

A National Effort for Motivating Indian Students and Teachers towards Algorithmic Research

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Abstract

During 2008-2015, twenty-two introductory workshops on graph and geometric algorithms were organized for teachers and students (undergraduate, post-graduate and doctoral) of engineering colleges and universities at different states and union territories of India. The lectures were meant to provide exposure to the field of graph and geometric algorithms and to motivate the participants towards research. Fifty-eight professors from TIFR, IITs, IISc, IMSc, CMI, ISI Kolkata, and other institutes and universities delivered invited lectures on different topics in the design and analysis of algorithms, discrete applied mathematics, computer graphics, computer vision, and robotics. The first four workshops were funded by TIFR, BRNS and IIT Kharagpur, and the remaining workshops were funded by the NBHM. In this paper, we present the salient features of these workshops, and state our observations on the national impact of these workshops.

1 Introduction

1.1 Background

Abū Jafar Muhammad al-Khwārizmī, a Persian astronomer and mathematician, wrote a treatise in 825 AD, *Kitāb hisāb al-adad al-hindī* (*Book on Calculation with Hindu Numerals*), which was translated into Latin in the early 12th century as *Liber Algorismi de numero Indorum* (*The Book of Algorismi on Indian Numerals*). The word “Algorism” – the Latin form of al-Khwārizmī’s name – came to be applied to any systematic work on ancient Indian-style computational mathematics. The present term “algorithm” is a distorted form of “algorism” [10].

The field of algorithms, which is at the very heart of computer science, has witnessed a number of significant advances during the last five decades. These advances include the development of faster algorithms and the discovery of certain natural problems for which all known algorithms are inefficient [12]. These startling results have kindled a keen interest in the area of algorithm design and analysis. Teaching and research in this foundational aspect of computing is therefore a natural and desirable thrust area.

As algorithms are also at the heart of every nontrivial computer application, computer scientists and professional programmers are expected to know about the basic algorithmic toolbox: structures that allow efficient organization and retrieval of data, frequently used algorithms and generic techniques for modeling, understanding and solving algorithmic problems. Hence, algorithmic studies form a major component of computer science programs in colleges and universities.

In the last four decades, graph and geometric problems have been studied by computer science researchers using the framework of design and analysis of algorithms [1, 33]. While graph algorithms have been studied for almost 300 years, graphs provide essential models for many application areas of computer science, and at the same time, they are fascinating objects of study in pure and applied mathematics. There have been a number of exciting developments in graph theory that are important for designers of algorithms. Correspondingly, the algorithmic viewpoint of computer science has stimulated much research in graph theory. Graph theory and graph algorithms are inseparably intertwined subjects.

On the other hand, the main impetus for the development of geometric algorithms came from the progress in computer graphics, computer-aided design and manufacturing [2]. In addition, algorithms are also designed for geometric problems that are classical in nature. The success of the field can be explained from the beauty of the geometry problems studied, the solutions obtained, and by the many application domains – computer graphics, geographic information systems, robotics and others, in which geometric algorithms play a crucial role.

1.2 Motivation

We know that basic algorithmic research has helped building today's computer technology and will keep on playing a crucial role in the achievement of tomorrow's technological breakthroughs. Therefore, we believe that algorithmic research is certainly important even for India.

At present, research is being carried out in India in several sub-areas of algorithms and results are being published in reputed conferences and journals in computer science and discrete applied mathematics. Algorithmic research started in India in premier academic institutes like TIFR, IITs and IISc, way back in the 70's. In recent years, algorithmic research is also carried out in computer industries in India including Microsoft Research, IBM Research, TCS Innovation Labs, etc. Today, computer industries in India provide financial support to projects on algorithmic research in Indian academic institutes and also provide fellowships to Ph.D. students working in algorithmic research.

The need for algorithmic research in India was felt in the late 70's. Perceiving future needs, the course "Design and Analysis of Algorithms" was introduced in the 80's in the undergraduate and postgraduate levels as a core course in premier institutes like IIT's, TIFR and IISc. This course used to cover asymptotic analysis of running time and space requirements for quantitatively measuring the efficiency of algorithms, searching and sorting algorithms, data structures, sequential algorithms for graph and geometric problems, NP-completeness, etc.

Designing efficient algorithms for graph and geometric problems within the framework of the design and analysis of algorithms started also around the same time. There were a few researchers in India (including S. N. Maheshwari (IIT Delhi), C. E. Veni Madhavan (IISc Bangalore), Subir Ghosh (TIFR Mumbai)), who were involved in algorithmic research during that time. In the 90's, Ph.D. and Master theses on algorithms for graph and geometric problems started coming up in increasing numbers, demonstrating the acceptability of algorithmic research in India. Many of these theses for designing efficient algorithms used mathematical

techniques from combinatorics, probability theory, graph theory, etc., and algorithmic techniques like greedy methods, divide and conquer, approximations, randomization, etc.

On the other hand, after personal computers became more and more available in India in the late 80's, a large number of scientists, engineers and administrators in India across all disciplines started using personal computers for solving problems arising in research, applications and in commerce. This gave rise to the need of computer programmers, as the IT industries proliferated. Naturally, several softwares were designed in 80's and 90's and many of them used basic algorithmic techniques and data structures that were routinely taught in the courses of "Design and Analysis of Algorithms" not only in IITs, IISc and TIFR but also in NITs, BITS Pilani, and several universities in India. Algorithmic studies gained further impetus in the 90's in India like anywhere in the world after personal computers became connected through networks, forming the world wide web. New types of algorithms like streaming algorithms, web-based algorithms, network algorithms, distributed algorithms, big data algorithms, etc. came into play in the last two decades.

Though the number of researchers working in India on graph and geometric algorithms has increased substantially in the last two decades, the number of active researchers in algorithms is still far lesser in India compared to the large number of bright students and teachers involved in studying and teaching computer science and discrete applied mathematics. In order to motivate them towards computer science research in general and algorithmic research in particular, twenty-two workshops of introductory lectures on graph and geometric algorithms were organized during 2008-2015 for teachers and students (undergraduate, post-graduate, and doctoral) of engineering colleges and universities at different locations in India.

Our workshop series may be viewed as a human resource development program for raising the level of algorithmic knowledge amongst Indian college and university students and teachers in computer science and discrete applied mathematics.

2 Workshop data

2.1 Organizational details

During 2008-2015, twenty-two workshops of introductory lectures on graph and geometric algorithms were organized at different states and union territories of India as shown in Tables I(a) and II(b), and in Figure 1.

Table I(a): Dates, Workshop Venues and Coordinators

No	Date	Workshop Venue	Coordinators
1	July 22-23 2008	Fr. Conceicao Rodrigues College of Engineering, Mumbai, Maharashtra	Subir Ghosh, Sunil Surve, Deepak Bhoir Vijay Bilolikar
2	October 31- November 2 2008	Indian Institute of Technology Kharagpur, West Bengal	Subir Ghosh, Partha Bhowmick Sudebkumar Pal
3	January 22-24 2009	Birla Institute of Technology & Science Pilani, Rajasthan	Subir Ghosh, Poonam Goel, Navneet Goel
4	July 15-18 2009	Indian Institute of Science Bangalore, Karnataka	Subir Ghosh, Sathish Govindarajan Sunil Chandran, Vijay Natarajan
5	January 7-9 2010	National Institute of Technology Tiruchirapalli, Tamilnadu	Subir Ghosh, Venkatesh Raman, Hemalatha Thiagarajan, A. Ramakalyan, Sunil Chandran
6	January 27-29 2010	Banaras Hindu University Varanasi, Uttar Pradesh	Subir Ghosh, Arun Agrawal, Pramod Mishra, Sudebkumar Pal, Sunil Chandran
7	March 25-27 2010	National Institute of Technology Rourkela, Odisha	Subir Ghosh, Banshidhar Majhi, Pankaj Sa Partha Goswami, Sudebkumar Pal
8	28-30 October 2010	Thapar University Patiala, Punjab	Subir Ghosh, Deepak Garg, Sandeep Sen Subhas Nandy
9	January 6-8 2011	PSG College of Technology Coimbatore, Tamilnadu	Subir Ghosh, R. S. Lekshmi, R. Nadarajan Venkatesh Raman
10	March 26-28 2011	National Institute of Technology Patna, Bihar	Subir Ghosh, Sawal Singh, Subhas Nandy Sathish Govindarajan, Md. Haider
11	October 21-23 2011	Indian Institute of Technology Guwahati, Assam	Subir Ghosh, R. Inkulu, Pinaki Mitra Sudebkumar Pal
12	January 10-12 2012	National Institute of Technology Surathkal, Karnataka	Subir Ghosh, Suresh Hegde, Shyam Kamath, P. Jidesh, Sathish Govindarajan
13	March 14-16 2012	Dhirubhai Ambani Institute of Information and Communication Technology, Gandhinagar, Gujarat	Subir Ghosh, Srikrishnan Divakaran, Rahul Muthu, Sathish Govindarajan, V. Sunitha
14	November 1-3 2012	PDPM Indian Institute of Information Technology, Design and Manufacturing Jabalpur, Madhya Pradesh	Subir Ghosh, Sudebkumar Pal, Pritee Khanna Sraban Mohanty
15	January 17-19 2013	Birla Institute of Technology & Science Pilani, Goa	Subir Ghosh, Tarkeshwar Singh, Anil Pundir B.M. Deshpande, Venkatesh Kamat
16	March 14-16 2013	Bengal Engineering and Science University, Shibpur, West Bengal	Subir Ghosh, Arindam Biswas, Sekhar Mandal Partha Bhowmick, Chandan Giri, Sanjay Saha
17	October 23-25 2013	National Institute of Technology Warangal, Andhra Pradesh	Subir Ghosh, R.B.V. Subramanyam Sandip Das, P V Subba Reddy
18	January 23-25 2014	University of Kerala & Indian Institute of Information Technology and Management, Trivandrum, Kerala	Subir Ghosh, Manoj Changat, T.K. Manoj Kumar, K. Satheesh Kumar, T. Radhakrishnan
19	March 6-8 2014	Indian Institute of Technology Roorkee, Uttarakhand	Subir Ghosh, Sudebkumar Pal Rajdeep Niyogi, Vaskar Raychowdhury
20	October 16-18 2014	Sikkim Manipal Institute of Technology & Sikkim Government College, Sikkim	Subir Ghosh, Sudebkumar Pal, Biswajit Deb Tejbanta Chingtham, Debabrata Purohit,
21	January 15-17 2015	Visvesvaraya National Institute of Technology, Nagpur, Maharashtra	Subir Ghosh, Manish Kurhekar, Abhiram Ranade, Ravindra Keskar, Umesh Deshpande
22	May 18-20 2015	University of Kashmir Srinagar, Kashmir	Subir Ghosh, Shariefuddin Pirzada Abhiram Ranade, S. M. K. Quadri

In addition to coordinators, two groups of people were involved in organizing these workshops. One group typically consisted of students and staff of host institutes who were involved essentially during the workshop days. The other group consisted of administrative and technical staff of School of Technology and Computer Science, TIFR who were involved from the preparatory phase till the completion of every workshop spanning a period of over 3-4 months.



Figure 1: Workshop venues

Mr. Raymond J. D’Mello worked as the secretary for this workshop series for the entire period of 2008-2015; he was assisted by Mr. John Barretto, Mr. Pravin N. Bhuwad, Mr. W. K. Gawade and Mr. Nitin S. Gawandi. Workshop websites for all the workshops during 2009-2015 were designed, developed, updated and maintained by Mr. Ravikumar Naik, and he also provided a necessary platform for online registration of participants.

2.2 Financial support

The first four workshops were funded by Tata Institute of Fundamental Research (TIFR), Indian Institute of Technology, Kharagpur (IITKGP), and the Board of Research in Nuclear Science (BRNS) of the Department of Atomic Energy, Government of India (see Table II(a)), and the remaining eighteen workshops were funded by the National Board for Higher Mathematics (NBHM), Department of Atomic Energy, Government of India (see Table II(b)). There was no registration fee for the workshops after the first three workshops. Thus the workshops were almost entirely funded by the above mentioned organizations. In addition, some host institutes provided small grants to cover some local expenses. In most cases, host institutes provided many facilities including auditoriums and guest houses at subsidized rates. Some invited speakers used their own travel grants for paying their air fares. Taking all these facts into consideration, it can be seen that budgets for the workshops were indeed quite low.

Table II(a): TIFR, BRNS and IITKGP Support

Workshop Venue	TIFR Grant	BRNS Grant	IITKGP Grant
CRCE Mumbai	Rs. 80,000/-	–	–
IIT Kharagpur	–	–	Rs. 2,15,000/-
BITS Pilani	Rs. 3,00,000/-	–	–
IISc Bangalore	Rs. 6,00,000/-	2,00,000/-	–

Table II(b): NBHM Support

Workshop Venue	NBHM Grant	Workshop Venue	NBHM Grant
BHU Varanasi	Rs. 2,60,000/-	IIITDM Jabalpur	Rs. 3,70,000/-
NIT Tiruchirapalli	Rs. 2,60,000/-	BITS Goa	Rs. 3,70,000/-
NIT Rourkela	Rs. 2,60,000/-	NIT Warangal	Rs. 3,70,000/-
Thapar University	Rs. 3,00,000/-	IIITM Kerala	Rs. 3,90,000/-
PSGTECH Coimbatore	Rs. 3,00,000/-	IIT Roorkee	Rs. 3,90,000/-
NIT Patna	Rs. 3,00,000/-	BESU Shibpur	Rs. 3,90,000/-
IIT Guwahati	Rs. 3,50,000/-	SMIT Sikkim	Rs. 4,10,000/-
NIT Karnataka	Rs. 3,50,000/-	VNIT Nagpur	Rs. 3,60,000/-
DAIICT Gandhinagar	RS. 3,50,000/-	University of Kashmir	Rs. 4,30,000/-

2.3 Invited lectures

In the 22 workshops, 266 invited lectures were delivered by 58 professors under 114 lecture titles. A complete list is given in Appendix. These lectures can be classified broadly into four categories: (i) Algorithmic Paradigms, (ii) Graphs and Algorithms, (iii) Geometry and Algorithms, and (iv) Geometry and Applications.

Under algorithmic paradigms, introductory lectures were delivered on different types of algorithms [8, 20]. Specifically, approximation algorithms [35], randomized algorithms [27], on-line algorithms [4], distributed algorithms [24], fixed parameter algorithms [29], quantum algorithms [30] and streaming algorithms [28] were covered.

Under graphs and algorithms, introductory lectures were delivered on graph theory [3, 14, 16, 18], networks [34], graph algorithms [20, 23] and scheduling [22]. Specific topics covered

from graph theory were graph matching, graph representations, extremal graphs, graph partitioning, probabilistic graphs, topological minors of graphs, expander graphs, graph coloring, graph spanners, and graph spectra. Similarly, specific topics covered from graph algorithms were planarity testing, network flow, shortest paths, social networks and wireless networks.

Under geometry and algorithms, introductory lectures were delivered on computational geometry [2, 13, 31], combinatorial geometry [11, 25] and digital geometry [19]. Specific topics of computational and combinatorial geometry covered were geometric graphs, facility location, convexity of points, art gallery problems, duality transformation, geometric data structures, geometric shortest paths, geometric spanners, Voronoi diagrams, centerpoint location, and geometric prune and search technique. Similarly, specific topics covered from digital geometry were shape transformations by local interchanges, algorithms for circles and spheres in digital space, isothetic covers for digital objects, anatomies of lines and circles in the light of number theory and on good digital distances.

Under geometry and applications, introductory lectures were delivered on computer graphics [5, 9, 26], computer vision [17, 32], visualization [15] and robotics [6, 21]. Specific topics covered from these application areas were 3D reconstruction from images and videos, projective geometry for graphics and computer vision, visibility maps for point clouds, motion structure using shape spaces, character animation, haptic rendering, symmetry and structure detection for 3D geometry, rendering using directional distance maps, cache friendly compressed representation of geometry, modeling for shape classes, manifold discovery in data, scalar field visualization, 3D surface reconstruction, graphics processor units, mesh generation, object recognition, a number theoretic introduction to geometry, and sequential and online algorithms for robot path planning.

2.4 Participants

Participants of the workshops were mainly undergraduate, post-graduate and doctoral students and teachers of computer science and discrete applied mathematics. They were required to have taken basic courses in discrete mathematics, data structures and algorithms at the undergraduate level. There were around fifty participants in the first workshop at CRCE Mumbai. Since then, the number of participants were at least 90 in every workshop. In some workshops, there were around 120 participants. The workshop at IIT Guwahati had the maximum number of 156 participants.

Normally, around three-fourths of the participants were from the host institute and its nearby institutes and university. The remaining participants, who were from the same state and from neighboring states, were provided with return train fares and free boarding and lodging. All participants were provided free lunch and snacks, and were issued certificates for attending workshops. Also, a standard textbook on algorithms (Indian edition) was gifted to every participant for further study.

3 Impact on the participants

3.1 Interaction

Usually, there were 4 or 5 invited one-hour lectures in a day. Many of these lectures were designed as interactive lectures. Around 10-20% of the participants took active part in such interactions and many of them got inspired by this opportunity to involve themselves. Interaction with speakers continued during lunch and tea breaks. The active participants were mostly

students from IITs, IISc, some NITs, BITS Pilani and ISI, Kolkata. Although around 15-30% participants were really at a loss during many of the lectures, the remaining participants followed several lectures even though they did not interact during the lecture. In fact, many of them met the speakers during breaks and clarified doubts. At the end of each workshop, we always had a feedback session. We received appreciation and valuable comments in feedback sessions. We also received emails from participants after almost every workshop on the merits and demerits of the workshop.

In every workshop, there was a session on open problems in which unsolved research problems on algorithms were stated and discussed. Many participants showed interest in the sessions on open problems.

3.2 Panel discussion

The general trend for computer science students in India is to take up a job in IT industry after completing B.Tech or M. Tech. degree. Most of them do not even consider that research in computer science could be his/her profession. In view of this, a panel discussion was conducted in every workshop on the topic “Is research a good career option?” Normally, some young invited speakers of the workshop took the role of panelists. During the discussions, participants asked panelists questions on various career options: What are the benefits in a research profession? What are the pitfalls in a research career? How much salary one can expect in research profession? What are the good institutes in India for doing research? How can one get a good research guide? Can good research be done in an industry? How do I convince my parents that research is a viable career option? Is it not better to do research in the USA rather than in India? During the panel discussions, extensive interactions took place due to diverse opinions and counter-opinions expressed by panelists and participants. We observed that panel discussion was an extremely effective way for motivating participants towards research.

4 Concluding remarks

We understand that the workshops have indeed inspired some students to seriously consider algorithmic research as a career option. In fact, professors of the various host institutes have informed us that some of their students, who are now pursuing Ph.D. program in computer science (in India or abroad), were actually motivated by our workshops. Moreover, the benefits from the exposure to the broad field of graph and geometric algorithms will certainly get reflected in the future profession of many of the participants. As organizers, we felt that it was worth making the effort, and we hope that in the interest of the nation and in the interest of algorithmic studies (in which India was a pioneer), such efforts will continue in the future.

References

- [1] A. V. Aho, J. E. Hopcroft and J. D. Ullman, *The Design and Analysis of Computer Algorithms*, Addison Wesley, 1975.
- [2] M. de Berg, M. van Kreveld, M. Overmars and O. Schwarzkof, *Computational Geometry: Algorithms and Applications*, Springer, 1997.
- [3] B. Bollobas, *Extremal Graph Theory*, Academic Press, London, 1978.
- [4] A. Borodin and R. El-Yaniv, *Online Computation and Competitive Analysis*, Cambridge University Press, Cambridge, 2005.
- [5] S.-W. Cheng, T. K. Dey and J. R. Shewchuk, *Delaunay Mesh Generation*, CRC Press, Florida, 2012.

- [6] Howie M. Choset, *Principles of robot motion: theory, algorithms, and implementation*, MIT Press, 2005.
- [7] F. Chung, *Spectral Graph Theory*, Americal Mathematical Society, 1997.
- [8] Thomas H. Cormen and Clifford Stein and Ronald L. Rivest and Charles E. Leiserson, *Introduction to Algorithms*, Prentice-Hall, India.
- [9] T. K. Dey, *Curve and Surface Reconstruction : Algorithms with Mathematical Analysis*, Cambridge University Press, 2006.
- [10] A. Dutta, *Decimal System in India*, In Encyclopaedia of the History of Science, Technology, and Medicine in Non-Western Cultures (Edited by Helaine Selin), pp. 1-14, Springer, Dordrecht, 2015.
- [11] H. Edelsbrunner, *Algorithms in Computational Geometry*, Springer, 1987.
- [12] M. R. Garey and D.S. Johnson, *Computers and Intractability: A Guide to the Theory of NP Completeness*, W. H. Freeman, 1979.
- [13] S. K. Ghosh, *Visibility Algorithms in the Plane*, Cambridge University Press, Cambridge, United Kingdom, 2007.
- [14] M.C. Golumbic, *Algorithmic Graph Theory and Perfect Graphs*, North-Holland Publishing Company, 2004
- [15] C. D. Hansen and C. R. Johnson (editors), *Visualization Handbook*, Academic Press, 2004.
- [16] F. Harary, *Graph Theory* AddisonWesley, Reading, MA, 1969.
- [17] R. Hartley and A. Zisserman, *Multiple View Geometry in Computer Vision*, Cambridge University Press, New York, 2nd edition, 2004.
- [18] T. Jensen and B. Toft, *Graph coloring problems*, Wiley, New York, 1995.
- [19] R. Klette and A. Rosenfeld, *Digital Geometry: Geometric Methods for Digital Picture Analysis*, Morgan Kaufmann, San Francisco, 2004
- [20] J. Kleinberg and É. Tardos, *Algorithm Design*, Pearson Education, Delhi, India.
- [21] J.C. Latombe, *Robot Motion Planning*, Kluwer Academic Publishers, Boston, MA, 1991.
- [22] J. Leung (editor), *Handbook of Scheduling: Algorithms, Models, and Performance Analysis*, CRC Press, 2004.
- [23] L. Lovasz and M. D. Plummer, *Matching Theory*, AMS Chelsea Publishing, vol 367, 2009.
- [24] N. Lynch, *Distributed Algorithms*, Morgan Kaufmann Publishers Inc., San Francisco, CA, USA, 1996.
- [25] J. Matousek, *Lectures on Discrete Geometry*, Springer, 2002.
- [26] A. Menache, *Understanding Motion Capture for Computer Animation and Video Games*, Morgan Kaufmann Publishers Inc., San Francisco, 1999.
- [27] R. Motwani and P. Raghavan, *Randomized Algorithms*, Cambridge University Press, 1997.
- [28] S. Muthukrishnan, *Data Streams: Algorithms and Applications*, Foundations and Trends in Theoretical Computer Science, vol. 1, no. 2, pp. 117-236, 2005.
- [29] R. Niedermeier, *Invitation to Fixed-Parameter Algorithms*, Oxford University Press, 2006.
- [30] M. Nielsen and I. Chuang, *Quantum Computation and Quantum Information*, Cambridge University Press, 2010.
- [31] F. P. Preparata and M. Shamos, *Computational Geometry: An Introduction*, Springer-Verlag, New York, 1985.
- [32] K. Salisbury, F. Conti, and F. Barbagli, *Haptic rendering: Introductory concepts*, IEEE Computer Graphics and Applications, vol. 24, no. 2, pp. 24–32, 2004.
- [33] R. E. Tarjan, *Data Structures and Network Algorithms*, SIAM, 1983.
- [34] R. M. Tripathy, A. Bagchi, and S. Mehta, *Towards combating rumors in social networks: Models and metrics*, Intelligent Data Analysis, 17, pp. 149-175, 2013.
- [35] V. Vazirani, *Approximation Algorithms*, Springer, 2003.

Appendix

Table: Invited Speakers and Lecture Topics

Invited speaker	Lecture title	Delivered at
John Augustine IIT Madras	(i) Algorithms for Big Data (ii) Introduction to Distributed Algorithms	VNIT Nagpur, IIITM Kerala, BITS Goa
Amitabha Bagchi IIT Delhi	(i) Information Diffusion on Social Networks (ii) Random Geometric Graphs and Wireless Networks	BESU Shibpur, NIT Patna, SMIT Sikkim BHU Banaras
Niranjan Balachandran IIT Bombay	(i) Graph Coloring	University of Kashmir BESU Shibpur DAIICT Gandhinagar IIITDM Jabalpur
Arnab Basu IIM Bangalore	(i) Probability and Graphs (ii) Big Data: The Future of Computing	Thapar University SMIT Sikkim, NIT Rourkela
Surender Baswana IIT Kanpur	(i) Shortest Paths in Presence of Vertex Failures (ii) Algorithms for Graph Spanners: Static, Dynamic and Fault Tolerant	NIT Patna IISc Bangalore
Amitava Bhattacharya TIFR Mumbai	(i) Graph Matching and Applications	PSGTECH Coimbatore IIT Guwahati
Partha Bhowmick IIT Kharagpur	(i) On Anomalies and Algorithms Related to Circles and Spheres in the Digital Space (ii) Geometry, Vision, and Graphics: A Number Theoretic Introduction (iii) Anatomies of Lines and Circles in the Light of Number Theory (iv) Isothetic Covers for Digital Objects: Algorithms and Applications	NIT Rourkela, NIT Warangal, BESU Shibpur, NIT Patna IIT Kharagpur, IIT Guwahati, IIITDM Jabalpur
Arijit Bishnu ISI Kolkata	(i) Art Locally, Change Globally: Shape Transformations by Local Interchanges (ii) Introduction to Randomized Algorithms (iii) Introduction to Network Flows (iv) Introduction to Computational Geometry	Thapar University NIT Rourkela, NIT Warangal, BESU Shibpur, IIT Kharagpur BHU Banaras, IIITDM Jabalpur, IIT Guwahati SMIT&SGC Sikkim*
Subhashis Banerjee IIT Delhi	(i) On Large Scale 3D Reconstruction from Images and Videos, (ii) Projective Geometry for Graphics and Computer Vision, (iii) Singular Value Decomposition and its Applications to Computer Vision	University of Kashmir Thapar University NIT Rourkela, NIT Warangal, BESU Shibpur, SGC Sikkim, BHU Banaras IIT Guwahati, IIT Roorkee
Sharat Chandran IIT Bombay	(i) Visibility Maps for Point Clouds, (ii) Using Shape Spaces for Structure for Motion, (iii) Geometric Data Structures Random	CRCE Mumbai, IIT Kharagpur, DAIICT Gandhinagar, IIITM Kerala
Sunil Chandran IISc Bangalore	(i) Geometric Representations of Graphs (ii) Rainbow Coloring of Graphs	NIT Tiruchirapalli NIT Rourkela, BITS Pilani, BHU Banaras BITS Goa

* indicates that the speaker had delivered two lectures in this workshop.

Invited speaker	Lecture topics	Delivered at
Parag Chaudhuri IIT Bombay	(i) Motion Graphs for Character Animation	Thapar University BESU Shibpur, IIT Guwahati, IIITM Kerala
Subhasis Chaudhuri IIT Bombay	(i) Haptic Rendering: How do we touch an object?	BESU Shibpur, NIT Karnataka, IIT Roorkee, SMIT Sikkim
Sandip Das ISI Kolkata	(i) Introduction to Approximation Algorithms (ii) Convexity of Point Sets (iii) Geometry Facility Location Problems (iv) Geometric Approximation Algorithms	University of Kashmir BESU Shibpur, VNIT Nagpur, NIT Rourkela NIT Warangal, NIT Tiruchirapalli, NIT Patna, IIT Kharagpur IISc Bangalore, BHU Banaras, IIT Guwahati IIITDM Jabalpur IIITM Kerala
Srikrishnan Divakaran, DAIICT Gandhinagar	(i) Introduction to Randomized Algorithms	DAIICT Gandhinagar
Ajit Diwan IIT Bombay	(i) Extremal Graph Theory, (ii) Graph Partitioning, (iii) Topological Minors of Graphs	NIT Tiruchirapalli IISc Bangalore PSGTECH Coimbatore NIT Karnataka
Sumit Ganguly IIT Kanpur	(i) Streaming and Semi-streaming Algorithms for Processing Massive Graphs, (ii) Introduction to Streaming Algorithms	BHU Banaras IIITDM Jabalpur
Deepak Garg Thapar University	(i) Introduction to Approximation Algorithms	Thapar University
Daya Gaur IIT Ropar	(i) Approximation Algorithms and Linear Programming, (ii) Introduction to Approximation Algorithms	Thapar University IISc Bangalore DAIICT Gandhinagar
Subir Ghosh TIFR Mumbai	(i) Computational Geometry, (ii) Robot Path Planning, (iii) Robot Path Planning: Offline and On-line Algorithms, (iv) Robot Online Algorithms for Searching and Exploration in the Plane (v) Online Algorithms in Computational Geometry (vi) Art Gallery Problems and Approximation Algorithms, (vii) Introduction to Network Flows (viii) Introduction to Approximation Algorithms	All workshops except at IIT Guwahati. (Two lectures were delivered at PSGTECH Coimbatore.)
Partha Goswami Calcutta University	(i) Introduction to Computational Geometry (ii) Geometric Data Structures (iii) Duality Transformation in Geometry	University of Kashmir* Thapar University BESU Shibpur, VNIT Nagpur, NIT Rourkela NIT Warangal, NIT Patna, SMIT Sikkim NIT Tiruchirapalli CRCE Mumbai, IIT Kharagpur, BITS Pilani, IISc Bangalore BHU Banaras, IIT Guwahati, NIT Karnataka, IIITDM Jabalpur*, IIT Roorkee

* indicates that the speaker had delivered two lectures in this workshop.

Invited speaker	Lecture topics	Delivered at
Sathish Govindarajan IISc Bangalore	(i) Geometric Graphs (ii) Introduction to Combinatorial Geometry	University of Kashmir NIT Tiruchirapalli NIT Rourkela, NIT Patna, BITS Pilani IISc Bangalore PSGTECH Coimbatore NIT Karnataka DAIICT Gandhinagar IIT Roorkee
Suresh Hegde NIT Karnataka	(i) Labeled Graphs and Digraphs: Theory and Applications	NIT Karnataka
R. Inkulu IIT Guwahati	(i) Finding Minimum Degree Spanning and Steiner trees, (ii) Buy-at-Bulk Network Design (iii) Graph and Geometric Shortest Paths	VNIT Nagpur, NIT Warangal, NIT Patna IIT Guwahati
Subrahmanyam Kalyanasundaram IIT Hyderabad	(i) Introduction to Randomized Algorithms	University of Kashmir VNIT Nagpur, IIITM Kerala, IIT Roorkee
Deepak Kapur UNM, Albuquerque	(i) Algorithms for Automated Reasoning and Symbolic Computations	IIT Roorkee
K. Murali Krishnan NIT Calicut	(i) Graph Representation of Codes and Decoding Algorithms	IISc Bangalore
Subodh Kumar IIT Delhi	(i) Accurate and Efficient Rendering of Detail using Directional Distance Maps, (ii) Cache Friendly Compressed Representation of Geometry (iii) Symmetry and Structure Detection for 3D Geometry	VNIT Nagpur, NIT Rourkela, NIT Patna IIT Kharagpur, BITS Pilani, BITS Goa DAIICT Gandhinagar IIT Roorkee
Anil Maheshwari Carleton University Ottawa	(i) Geometric Spanners	CRCE Mumbai IISc Bangalore
S.N Maheshwari IIT Dehi	(i) Network Flows and Applications	IIT Guwahati
Amitabha Mukerjee IIT Kanpur	(i) Robot Motion Planning, (ii) Geometric Modeling for Shape Classes, (iii) Manifold Discovery in High-Dimensional Data	University of Kashmir Thapar University NIT Warangal, SMIT Sikkim, DAIICT Gandhinagar, IIITDM Jabalpur, BITS Goa IIT Roorkee
Niloy Mitra IIT Delhi	(i) Scalar Field Visualization, (ii) Symmetry and Structure Detection for 3D Geometry	IIT Kharagpur BITS Pilani
Anurag Mittal IIT Madras	(i) Graph-based Algorithms in Computer Vision	PSGTECH Coimbatore
Sudhir Mudur Concordia University Montreal	(i) The 3D Surface Reconstruction Problem and Some Solutions	BITS Goa
Jayanta Mukerjee IIT Kharagpur	(i) In the Quest for Good Digital Distances	IIT Kharagpur
Krishnendu Mukerjee ISI Kolkata	(i) Distributed Leader Election	NIT Patna
Subhas Nandy ISI Kolkata	(i) Introduction to Randomized Algorithms (ii) Voronoi Diagram	Thapar University NIT Rourkela, CRCE Mumbai, BITS Pilani IIT Kharagpur, IISc Bangalore, BHU Banaras

Invited speaker	Lecture topics	Delivered at
P. Narayanan IIIT Hyderabad	(i) Graphics Processor Units: For Graphics and Beyond	IISc Bangalore
Vijay Natarajan IISc Bangalore	(i) Scalar Field Visualization: Level Set Topology (ii) Symmetry in Scalar Fields	IIT Kharagpur, BITS Pilani, IISc Bangalore PSGTECH Coimbatore NIT Karnataka, BITS Goa, NIT Nagpur
N. S. Narayanaswamy IIT Madras	(i) Special Classes of Intersection Graphs (ii) Perfect Graphs, (iii) Graph Classes with Interesting Structural Properties, (iv) Tree Path Assignments: An extension of the Consecutive Ones Property, (v) Algorithms for Perfect Graphs	NIT Tiruchirapalli NIT Warangal, IISc Bangalore, IIT Guwahati, NIT Karnataka, IIITDM Jabalpur, IIT Roorkee
Sudebkumar Pal IIT Kharagpur	(i) Link Paths and Reflection Visibility Problems, (ii) Geometric Data Structures	NIT Rourkela, SMIT Sikkim, NIT Patna NIT Tiruchirapalli CRCE Mumbai, BITS Pilani, IISc Bangalore BHU Banaras, IIT Guwahati, NIT Karnataka, DAIICT Gandhinagar, IIITDM Jabalpur, IIITM Kerala, IIT Roorkee
Sachin Patkar IIT Bombay	(i) Network Flows and Applications	BITS Goa
Shariefuddin Pirzada UK Srinagar	(i) Graph Spectra and Applications	University of Kashmir
Venkatesh Raman IMSc Chennai	(i) Fixed Parameter Algorithms	NIT Tiruchirapalli IISc Bangalore PSGTECH Coimbatore
Abhiram Ranade IIT Bombay	(i) Graph Partitioning, (ii) Geometric Packing (iii) Algorithms for Precedence Constrained Scheduling, (iv) Mumbai Navigator, (v) Some Formulations of the Genome Assembly Problem	VNIT Nagpur, NIT Warangal, BITS Goa BESU Shibpur, SMIT Sikkim, BITS Pilani PSGTECH Coimbatore DAIICT Gandhinagar* BHU Banaras, IIITM Kerala, IIT Roorkee
M. Panduranga Rao IIT Hyderabad	(i) Introduction to Quantum Algorithms	BITS Goa
Tathagata Ray BITS Hyderabad	(i) Mesh Generation	NIT Warangal, IIITM Kerala
Sasanka Roy CMI Chennai	(i) Introduction to Computational Geometry (ii) Voronoi Diagram	VNIT Nagpur, IIT Guwahati, PSGTECH Coimbatore, BITS Goa
Yogish Sabharwal IBM Delhi	(i) Randomized Techniques in Geometry	IIT Kharagpur
Sudeep Sarkar USF, Tampa	(i) Graphs and Object Recognition	IISc Bangalore

* indicates that the speaker had delivered two lectures in this workshop.

Invited speaker	Lecture topics	Delivered at
Swami Sarvattomananda RKMVU, Belur	(i) Planarity Testing of Graphs, (ii) Voronoi Diagrams, (iii) Geometric Data Structures (iv) Helly's Theorem and Centre Point (v) Computing Center Point Using the Prune and Search Technique, (vi) Prune and search Technique in Geometry	Thapar University BESU Shibpur, NIT Rourkela, NIT Patna SGC Sikkim, CRCE Mumbai, BITS Pilani IIT Kharagpur, IISc Bangalore, BHU Banaras, PSGTECH Coimbatore, IIITM Kerala
Saket Saurabh IMSc Chennai	(i) Fixed Parameter Algorithms (ii) Preprocessing with Guarantee	NIT Rourkela, NIT Patna, NIT Karnataka
Sandeep Sen IIT Delhi	(i) A Short Guided Tour of Randomized Algorithms	BITS Pilani IISc Bangalore
Naveen Sivadasan IIT Hyderabad	(i) Introduction to On-line Algorithms	Thapar University VNIT Nagpur, NIT Warangal, NIT Karnataka
K. V. Subrahmanyam CMI Chennai	(i) Expander Graphs and their Applications (ii) Network Flows and Applications	NIT Tiruchirapalli NIT Patna
C. R. Subramanian IMSc Chennai	(i) Introduction to Randomized Algorithms (ii) Randomized Algorithms for Counting Problems	NIT Tiruchirapalli BHU Banaras, IISc Bangalore, PSGTECH Coimbatore, NIT Karnataka, BITS Goa
Ambat Vijayakumar CUSAT, Cochin	(i) Graph Dynamics	IIITM Kerala
Nisheeth Vishnoi Microsoft Bangalore	(i) Hardness of Approximation	NIT Karnataka